DIN 65SD4528

DEVELOPMENT OF ENERGY DISSIPATING PLASTIC HONEYCOMB

QUARTERLY PROGRESS REPORT NO. 2

OCTOBER 1 THROUGH DECEMBER 31, 1965

Contract No. 951172

by

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SECTION 1

SUMMARY

An order was placed with Honeycomb Products, Incorporated for the tee and dovetail design specimens. These specimens will be fabricated to the dimensions shown in the Program Plan, and will be fabricated from glass cloth, the preferred design.

Preliminary testing of the materials received from Hexcel Products, Incorporated has indicated that, due to unknown causes, their material does not perform as well as an energy absorber as does similar material fabricated by Honeycomb Products, developed and tested under Contract 950564. The Hexcel equivalent to the previously designed optimum configuration fails in a very orderly manner, but the specific energy is relatively low compared with the same material produced by Honeycomb Products.

Due to manufacturing problems, the new high temperature resin specimens to be furnished by Hexcel will not be available until December 27, 1965.

As a result of the low values obtained with the Hexcel specimens, the thinned dip specimens are being reordered from Honeycomb Products. This is necessary because the high density specimens made by Hexcel did not develop sufficient bulk strength to limit the material by the strength of the node bond line. The purpose of thin-dipping is to increase the bond strength by reducing the internal stresses formed during curing. To properly evaluate this thin-dipping procedure it is necessary to start with a high strength material, such as that fabricated by Honeycomb Products, and alter their manufacturing procedure by thin-dipping the specimens.

Because of the differences existing in the manufacturing procedures of the two manufacturers, new, high temperature resin specimens are also being procured from Honeycomb Products. This will avoid the possibility of judging a new resin material as a low energy absorber, when the manufacturing process may be the true item of concern.

SECTION 2

PROCUREMENT OF SPECIMENS

2.1 TEE AND DOVETAIL DESIGNS

Honeycomb Products, Incorporated was the low bidder on these two items. In addition to being the low bidder, this vendor agreed to fabricate the specimens exactly as shown on the drawings in the Program Plan. This vendor can also fabricate the specimens from glass cloth, which is the preferred design. Glass was preferred because all past testing has been performed on glass cloth specimens; it will therefore be easier to compare the new results with the existing data to obtain the relative performance of tee, dovetail and hexagonal cell configurations. Both items are scheduled to be delivered to General Electric on December 27, 1965.

2.2 THINNED DIP AND HIGH TEMPERATURE RESIN SPECIMENS

By common agreement between JPL and GE, the thinned dip specimens and one high temperature resin test specimen previously obtained from Hexcel are being reordered from Honeycomb Products. These specimens are being procured directly by the customer for shipment to General Electric. The reasons for this additional procurement are discussed in Section 3.3. These specimens are expected to be shipped to General Electric during the week of January 3, 1966.

In addition to the above specimens, specimens having a special cure cycle are being ordered from the same vendor. These specimens will be used to determine the effect of the in-process cure cycle heat input on energy absorption and node bond line strength. This is discussed further in Section 4.

As a result of these changes, the schedule has been revised. A new schedule, having the same contract end date is presented in Section 5.

Comparison tests of the paper core material and the glass cloth core material have shown that the glass cloth core is superior. The paper core specimens performed poorly in the crushing tests.

Test specimens have been prepared using node bond adhesive additives. These modifiers exhibit good compatibility with the base resin. Shear strength tests will be performed on these specimens in January 1966.

SECTION 3

TESTING

3.1 SPECIMENS

The following specimens were tested during this reporting period. Copies of the load-deflection graphs are included in the Appendix to this report.

Each test number is keyed to the Task, as outlined in the Program Plan, by the first letter and the first number of the designation. The third digit refers to a particular specimen of a series. Tests indicated by an "X" are performed on specimens which are not specifically called out in the Program Plan.

a. Test B-1-a (Paper Core)
   3/16 cell, 20 lb kraft paper, 11 pcf, 2 in. x 2 in. x 2 in.

b. Tests B-1-b through B-1-d
   Same as test B-1-a except specimen size is 4 in. x 4 in. x 4 in.

c. Test B-3-a (Thinned Dip)
   3/16 cell, HRP, 11 pcf, 112 cloth, thinned dip, 2 in. x 2 in. x 2 in.

d. Test B-3-b
   Same as B-3-a except specimen size is 4 in. x 4 in. x 4 in.

e. Test B-3-c
   3/16 cell, HRP, 14 pcf, 112 cloth, thinned dip, 2 in. x 2 in. x 2 in.

f. Test B-3-d
   Same as B-3-c except specimen size is 4 in. x 4 in. x 4 in.

g. Test X-1-a (Standard Hexcel HRP)
Standard Hexcel 3/16 HRP, 11 pcf, except 112 cloth, 2 in. x 2 in. x 2 in.

h. Tests X-1-b through X-1-d
Same as X-1-a except specimen size is 4 in. x 4 in. x 4 in.

i. Tests X-2-a through X-2-d (Post cured Standard Hexcel HRP)
Standard Hexcel 3/16 HRP, 11 pcf, except 112 cloth, 2 in. x 2 in. x 2 in.
Specimens post cured at 400°F for 1, 2, 5, and 20 hours respectively. (Load deflection graphs for X-2-b through X-2-d are not included in this report)

3.2 TESTING MACHINE

The 2 in. x 2 in. x 2 in. specimens were tested on an Instron tensile testing machine, while the 4 in. x 4 in. x 4 in. specimens were tested on the new specially designed testing machine described on page 14 of the Program Plan.

3.3 DISCUSSION OF TESTS RESULTS

A summary of the results obtained in the tests is presented in Table 3-1.

3.3.1 PAPER CORE MATERIAL

The first test performed on this material (B-1-a) was on a specimen having dimensions of 2 in. x 2 in. x 2 in. This specimen failed in an orderly manner; that is, the material did not break apart at the bond lines, but crushed into small particle sizes. In the three following tests on 4 in. x 4 in. x 4 in. specimens (B-1-b, B-1-c, B-1-d), the material broke apart in large pieces, especially at the beginning of the tests, and yielded a very low value of energy absorption. (Refer to Table 3-1 and the photo of specimen B-1-b, partially crushed, which appears on the load-deflection graph for Test B-1-b in the Appendix.) This change in specimen behavior with change in specimen size has never been experienced

Table 3-1. Tests Results

	Test	Principal Steady State Stress (psi)	Density (pcf)	σ / ρ (inch x 10^{-6})	Stroke Eff (%)
Paper	B-1-a	730	9.8	.130	66
	B-1-b	226	9.5	.042	72
	B-1-c	357	9.5	.064	68
	B-1-d	298	9.5	.054	66
Thinned Dip-11	B-3-a	1250	10.4	.208	70
	B-3-b	1370	10.0	.237	67
Thinned Dip-14	B-3-c	1870	13.2	.244	56
	B-3-d	1850	12.8	.250	66
Standard	X-1-a	1300	11.0	.202	58
	X-1-b	1370	10.7	.221	63
	X-1-c	1370	10.7	.221	65
	X-1-d	1370	10.7	.221	64

NOTE: Stress density ratios, rather than specific energy, have been used for the preliminary comparison evaluation.

before in all of the testing performed on this and previous contracts. It is therefore concluded that the test on the small specimen was not a representative test. Tests on other specimens of both sizes, discussed below, showed no effect due to specimen size. The apparent weak link in this paper-resin system is the node bond line strength. Because the glass core system is so superior, it is recommended that no further effort be expended in developing a paper core material, and that no further tests be performed on it.

3.3.2 HEXCEL SEMI-STANDARD 11 PCF MATERIAL

This material was ordered from Hexcel Products Inc. with the specification that it was to be identical to their HRP material except for the type of glass cloth. Number 112 glass cloth was specified instead of their standard GF 12 cloth.

The 11 pcf material (X-1-a, -b, -c, -d) crushed in a very orderly manner, but its energy absorbing capability is less than that of the equivalent material previously procured from Honeycomb Products Inc. "Orderly" crushing means that the material does not break apart at the bond lines but crumbles into a powder or at least very small size chips. The values obtained are shown in Figure 3-1 and Table 3-1. Also plotted, for comparison, on Figure 3-1 are values obtained in past tests on the Honeycomb Products 3/16 cell, HTP material. The reasons for the difference must be due to manufacturing processes and techniques. Because this information is proprietary with the two manufacturers, there is no way of completely singling out the reasons.

3.3.3 THINNED DIPPED SPECIMENS (HEXCEL)

For the 11 pcf material (B-3-a, -b), the stress and energy absorbing values remained the same as the values for the standard dipped material. This is to be expected since the purpose of thin dipping is to reduce internal curing stresses and thereby reduce the possibility of bond line failures. In the case of the 11 pcf standard dip material, however, there was no problem with bond line failures in the regular material. Therefore thin dipping had no noticeable effect.

The 13 pcf material (B-3-c, -d) did not crush in the same manner as the 11 pcf material. While the crushing was orderly and the stress values consistent between specimens, there existed a series of stress build-ups and reliefs during the cycle. A graphic presentation of this phenomenon can be seen in the test graph for specimen B-3-d, in the Appendix.

This response, which corresponds to a great number of cyclic load interruptions, occured in past tests on very high density specimens. For example, during testing of 3/16-inch-11 pcf, 3/16-inch-14 pcf, and 1/4-inch-12 pcf material in the Phase II portion of Contract JPL 950564, this type of load response was observed. In many cases, during this past testing, the material broke apart at the bond lines before completion of the stroke because the reaction of the machine permitted the specimen to tilt. This did not occur in the present tests. In an attempt to evaluate this occurence, the tests were interrupted to

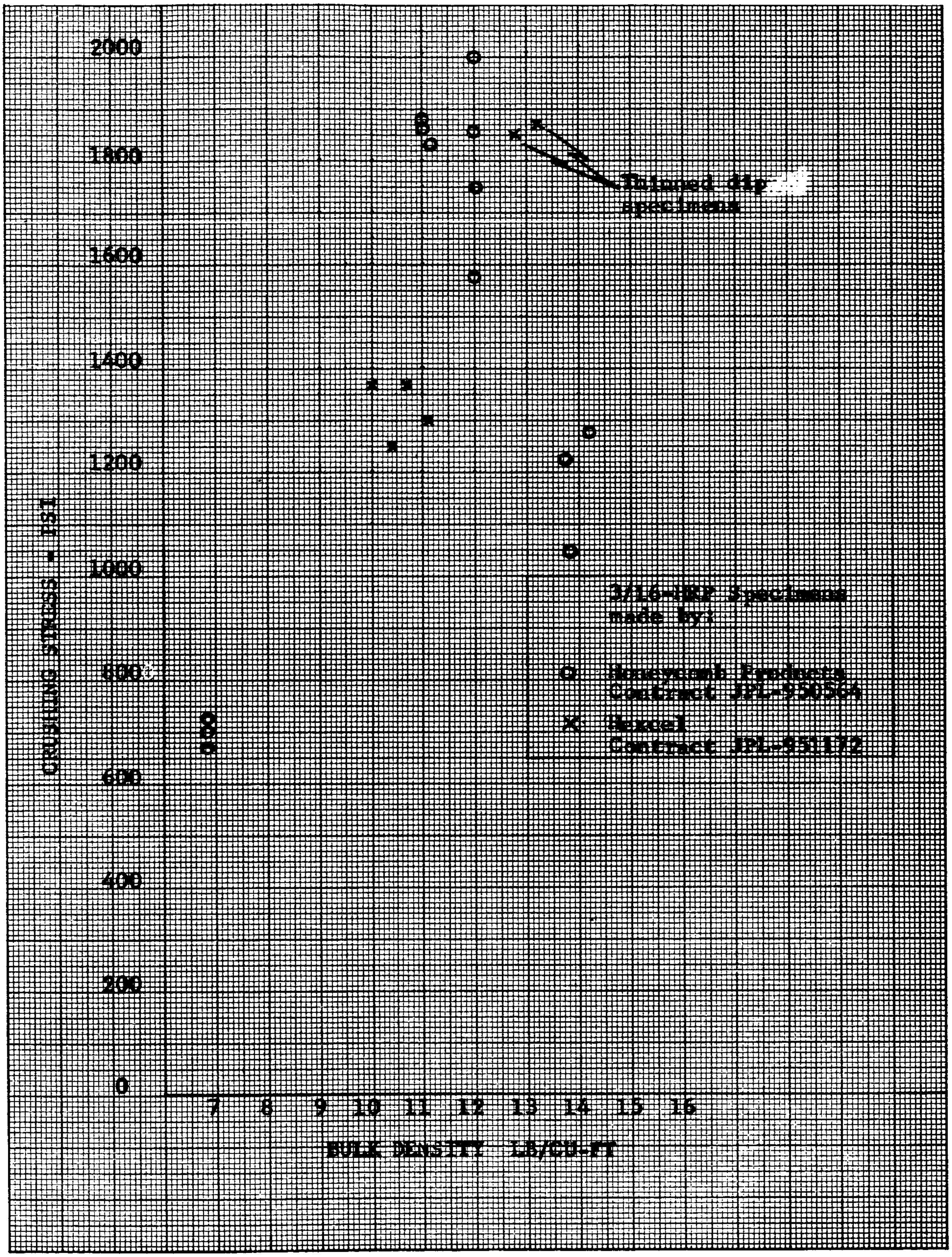


Figure 3-1. Crushing Strength versus Bulk Density

observe the area on the specimen under the crosshead, both before and after the time at which this load variation occured. No change in appearance was observed. This indicates that this disturbance must be due to a change in the failure mode of the material and must be minute in structure. While the load drops off considerably during this shock, there is essentially no change in the specific energy. It is possible that during testing at higher velocity this phenomenon may not be observable, and may therefore be unimportant. By the same reasoning, this shocking could also be responsible for causing the material to fail at higher velocities. This item will be given further consideration later in the program when dynamic testing is being performed.

Because of the relatively low values for a given density, obtained with the Hexcel material, insufficient data is available to properly evaluate the effect of thin dipping. It was therefore suggested by GE and approved by JPL that additional thinned dip specimens be procured from Honeycomb Products Inc. and tested.

3.3.4 HIGH TEMPERATURE RESIN SPECIMENS

Because of the differences in performance in the materials supplied by the two manufacturers, there is doubt that other type specimens, such as new high temperature resin systems, would perform equally well when manufactured by the two companies. The difference in manufacturing techniques may well affect the properties of other resin systems, and without knowing the details of the processes, it is impossible to predict which system will be best. It was therefore suggested that the specimens for Task B-2, the high temperature resin systems specimens, be obtained from both manufacturers and evaluated.

SECTION 4

IMPROVED BOND MATERIAL STUDY

4.1 GLASS FIBER BONDS

The manufacturing procedures used at the Honeycomb Products, Inc. plant were reviewed. From discussions with the Director of Manufacturing it was determined that the glass cloth used was treated with an aminosilane finish in order to improve bonding between the resin and the glass. This is in line with current best accepted commercial practice, and no immediate reason was apparent for modifying this procedure. The node bond adhesive is a high modulus condensation resin which cures at room temperature, and it is particularly adapted to the process developed by Honeycomb. The basic adhesive and glass cloth impregnating systems, therefore, are highly specialized entities adapted to the process.

From enlarged photomicrographs of failed honeycomb specimens (in investigations performed by JPL) it was apparent that failures were taking place between the phenolic resin binder and the surface of the glass yarn of the reinforcement. A series of experiments was therefore proposed, in which the effect of cure on the adhesion properties of the resin would be evaluated. First experiments were performed with 3/16-inch cell Hexcel honeycomb. Specimens were post-cured for 1, 2, 5, and 20 hours at 400°F, then crushed under static conditions. The crushing load was found to be essentially constant for all specimens and was the same as the original, untreated value. A second set of experiments is to be performed on HTP material, in which the dipping cycle is modified so that less total heat input will be generated in the honeycomb structure. Two levels of cure, both less than the one presently used, will be investigated.

4.2 RESIN MODIFICATION

The node bond adhesive has been modified using the following additives:

a. Asbestos micro fibers

b. SiC whiskers

c. Butvar resins

These modifiers exhibited good compatibility with the base resin. Test specimens have been prepared, and shear strength values are being obtained.

SECTION 5

SCHEDULE REVISION

The schedule shown in Figure 5-1 incorporates all the changes made to date in the program. In order to allow sufficient time for procurement and testing of the additional thinned dip specimens and the high temperature resin specimens without changing the end date of the contract, it is necessary to perform the column effects evaluation in the same time period as originally scheduled. This means that the material to be evaluated must be chosen prior to the time of completing Task A. As can be seen from the new schedule, this material selection should be made at the completion of Tasks A-1 and A-2, rather than at the completion of Tasks A-3 and A-4 as originally planned. It is not believed that this will detract from the usefulness of the column tests.

REV. 9/10/65, 12/14/65

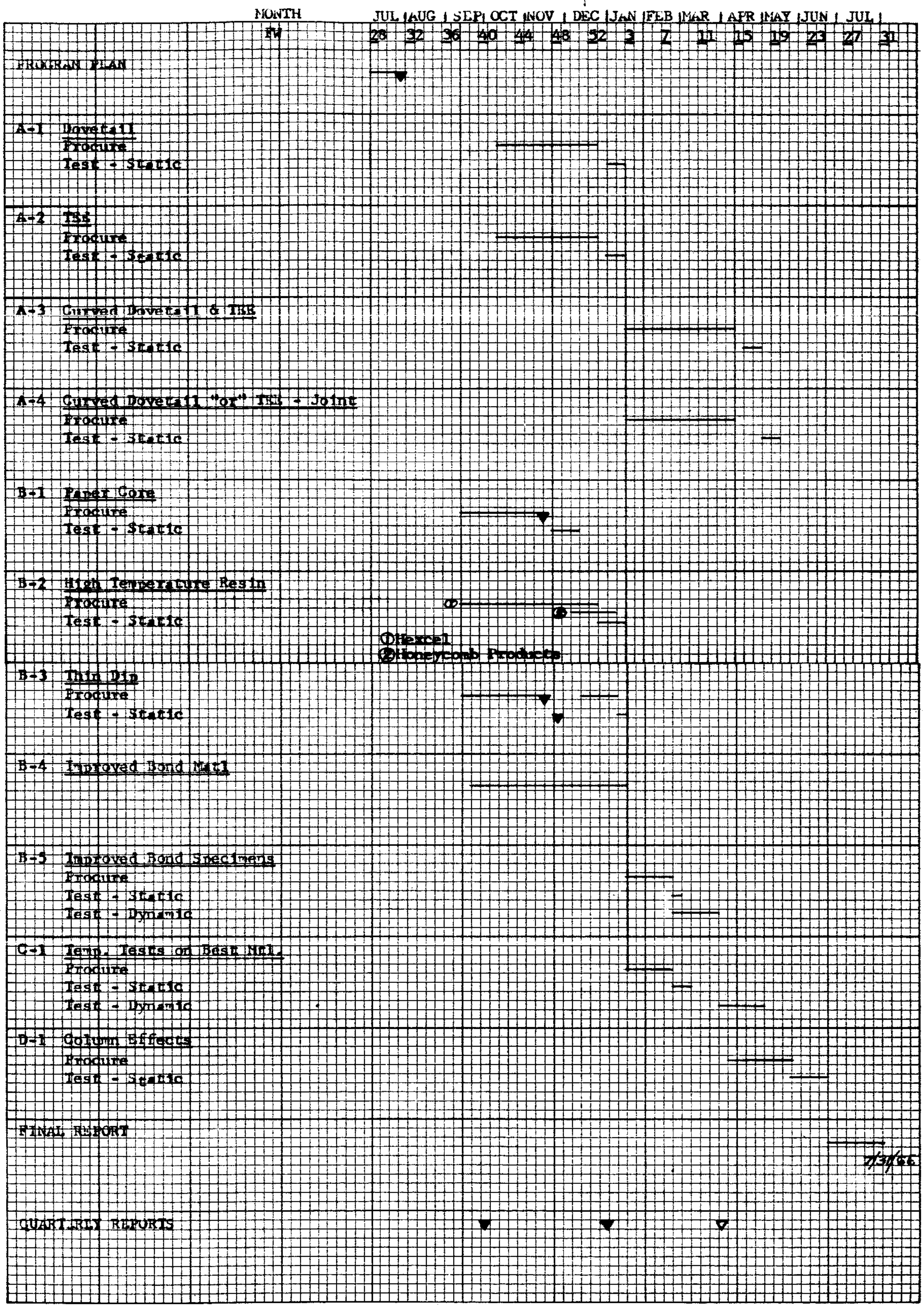


Figure 5-1. Revised Program Plan

SECTION 6

ACTUAL VERSUS PLANNED MAN-HOUR UTILIZATION

Figure 6-1 is graph of actual versus planned man-hour utilization for the period of October 1, 1965 through December 31, 1965.

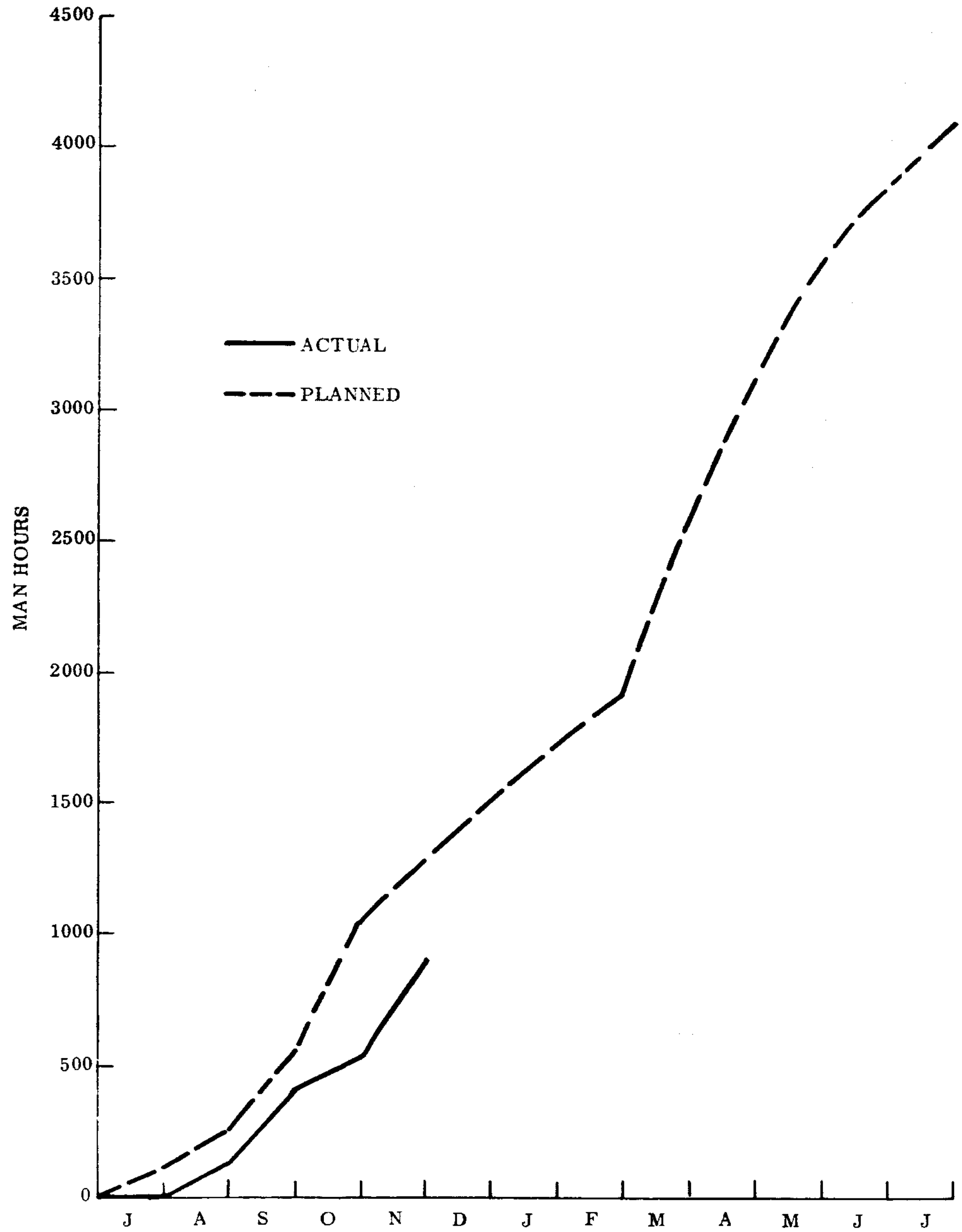


Figure 6-1. Actual versus Planned Man-Hour Utilization

SECTION 7

WORK PLANNED FOR NEXT QUARTER

The following work will be performed during the next quarter:

a. Flat specimens of the dovetail and tee designs will be evaluated. This will complete Tasks A-1 and A-2.

b. The curved specimens of the dovetail and tee designs for Tasks A-3 and A-4 will be ordered.

c. The new high temperature resin specimens from both manufacturers will be evaluated, thus completing Task B-2.

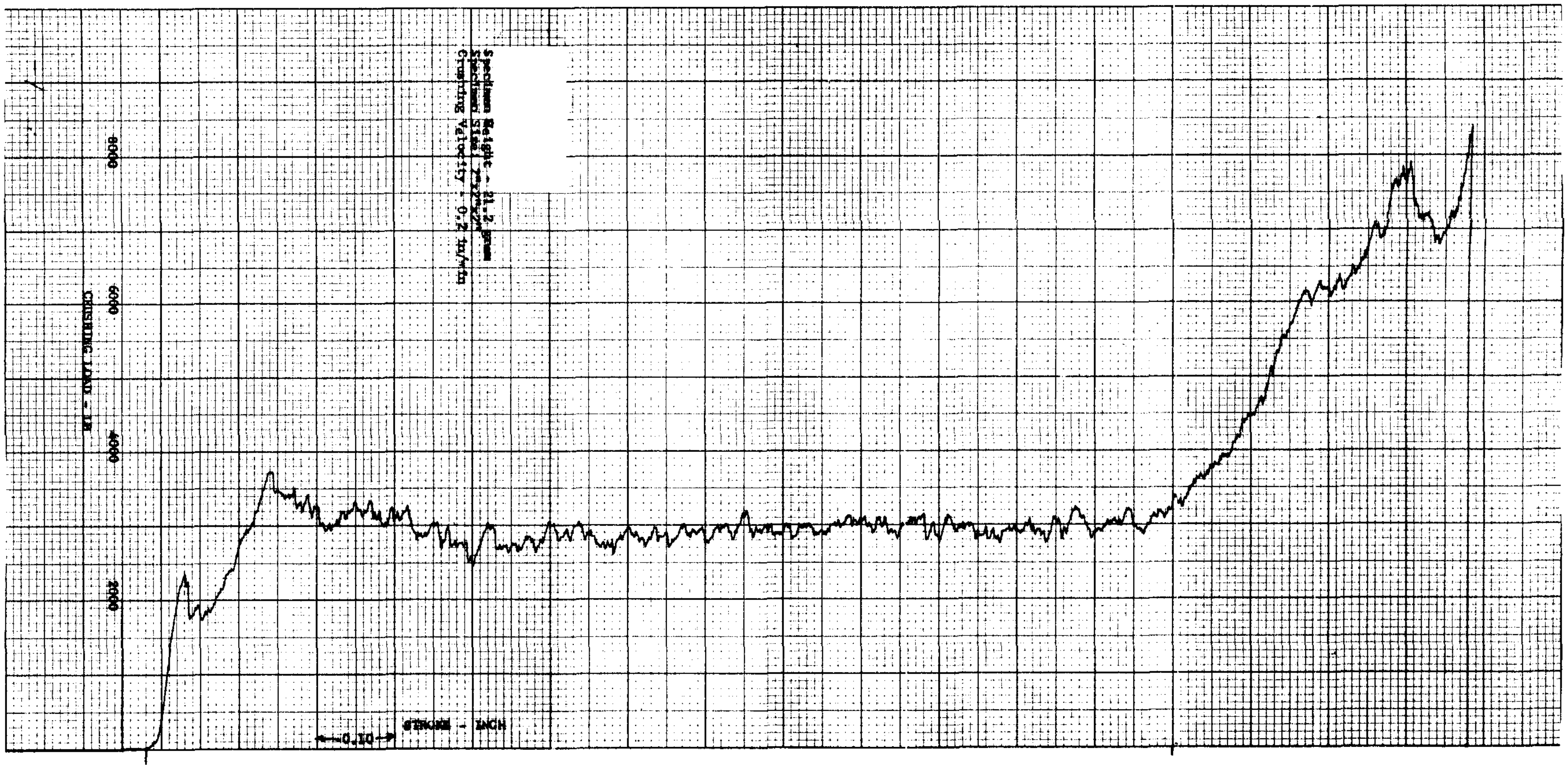
d. The new thinned dip specimens from Honeycomb Products, Inc. will be evaluated, thus completing Task B-3.

e. The improved bond specimens for Task B-4, will be procured. Both static and dynamic testing will be completed.

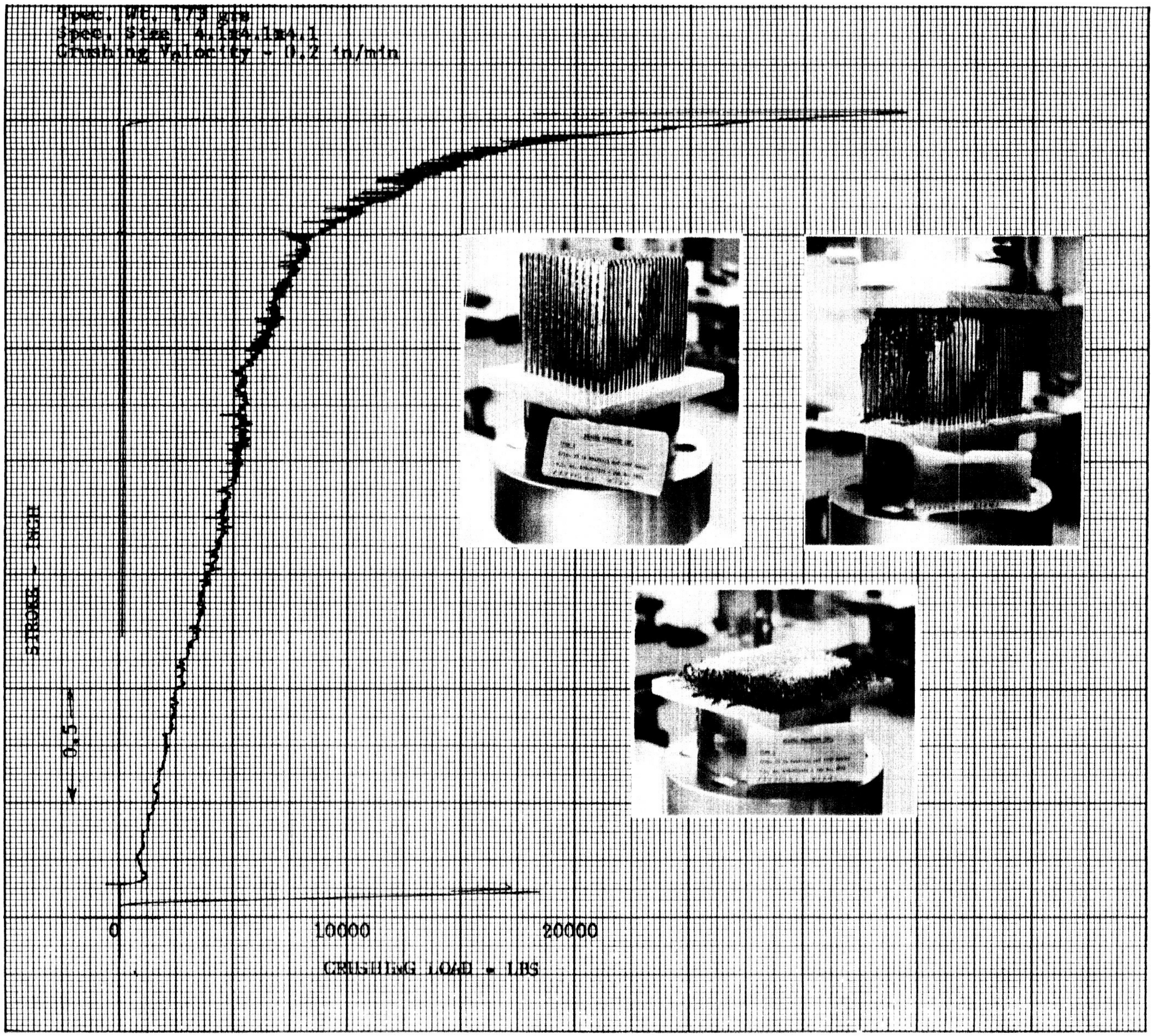
f. Specimens for the temperature tests, Task C-1, will be procured and statically tested.

APPENDIX A

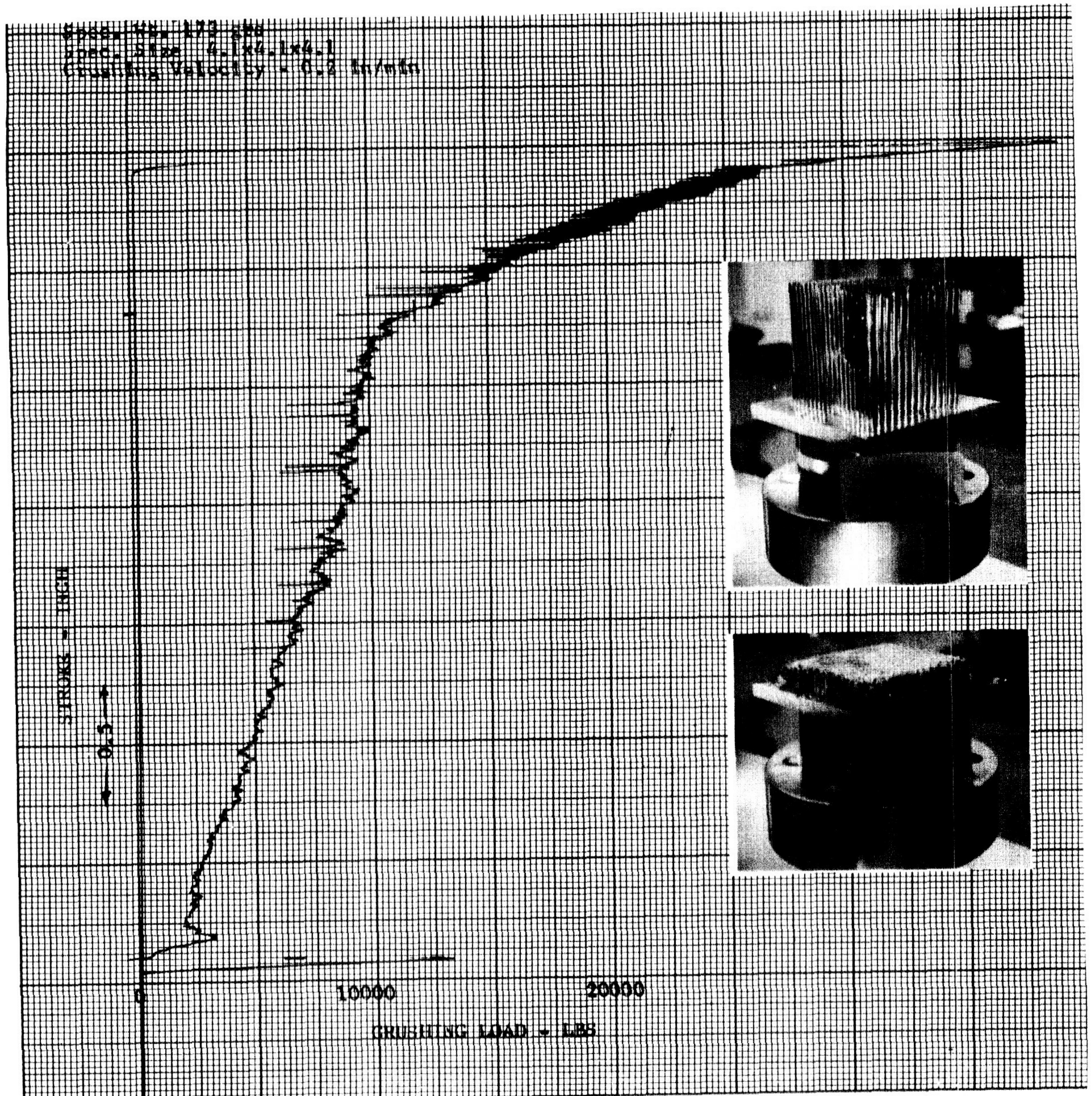
LOAD DEFLECTION GRAPHS



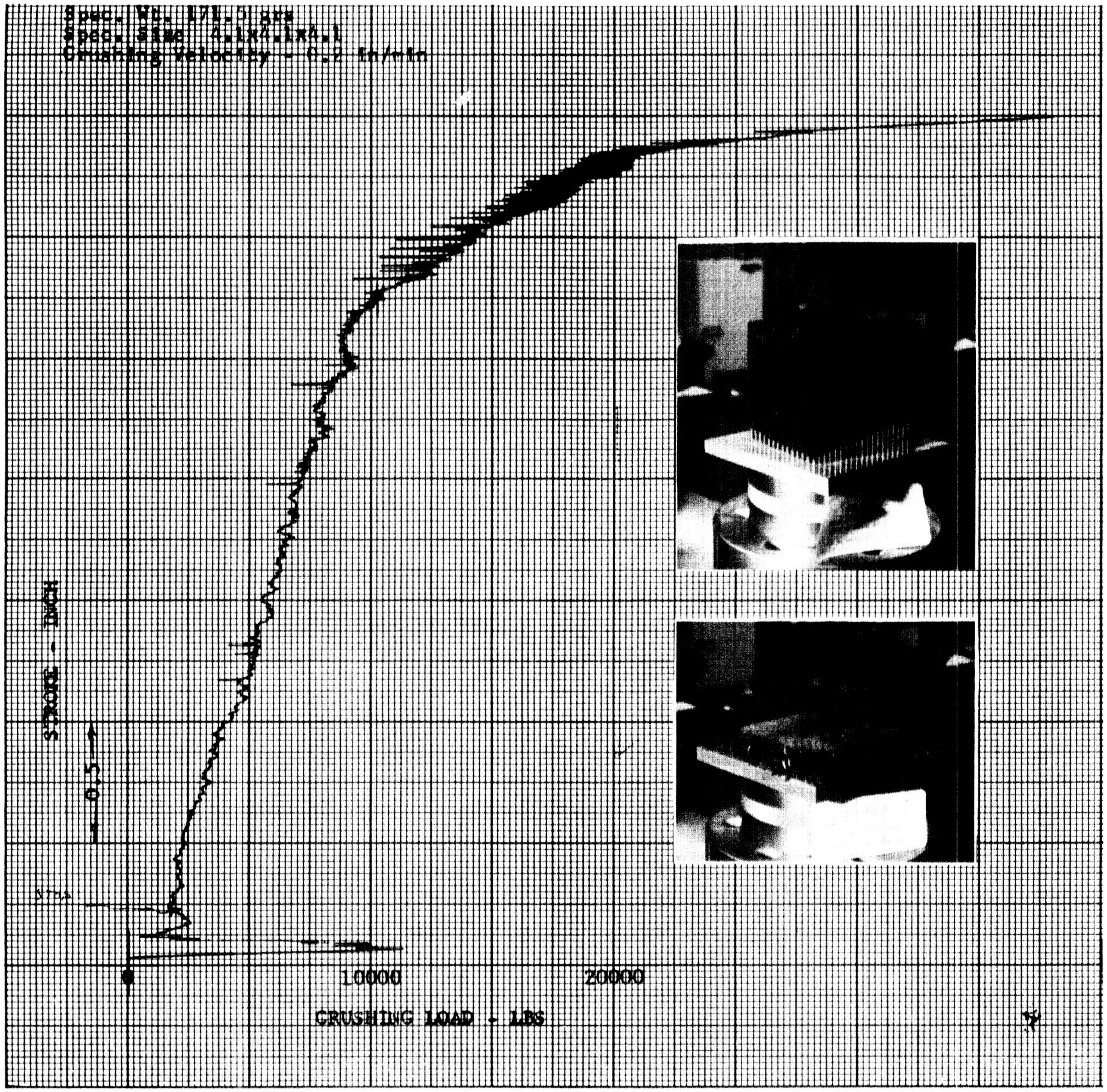
Test B-1-a (Task B-1) - Hexcel Paper Core Specimen



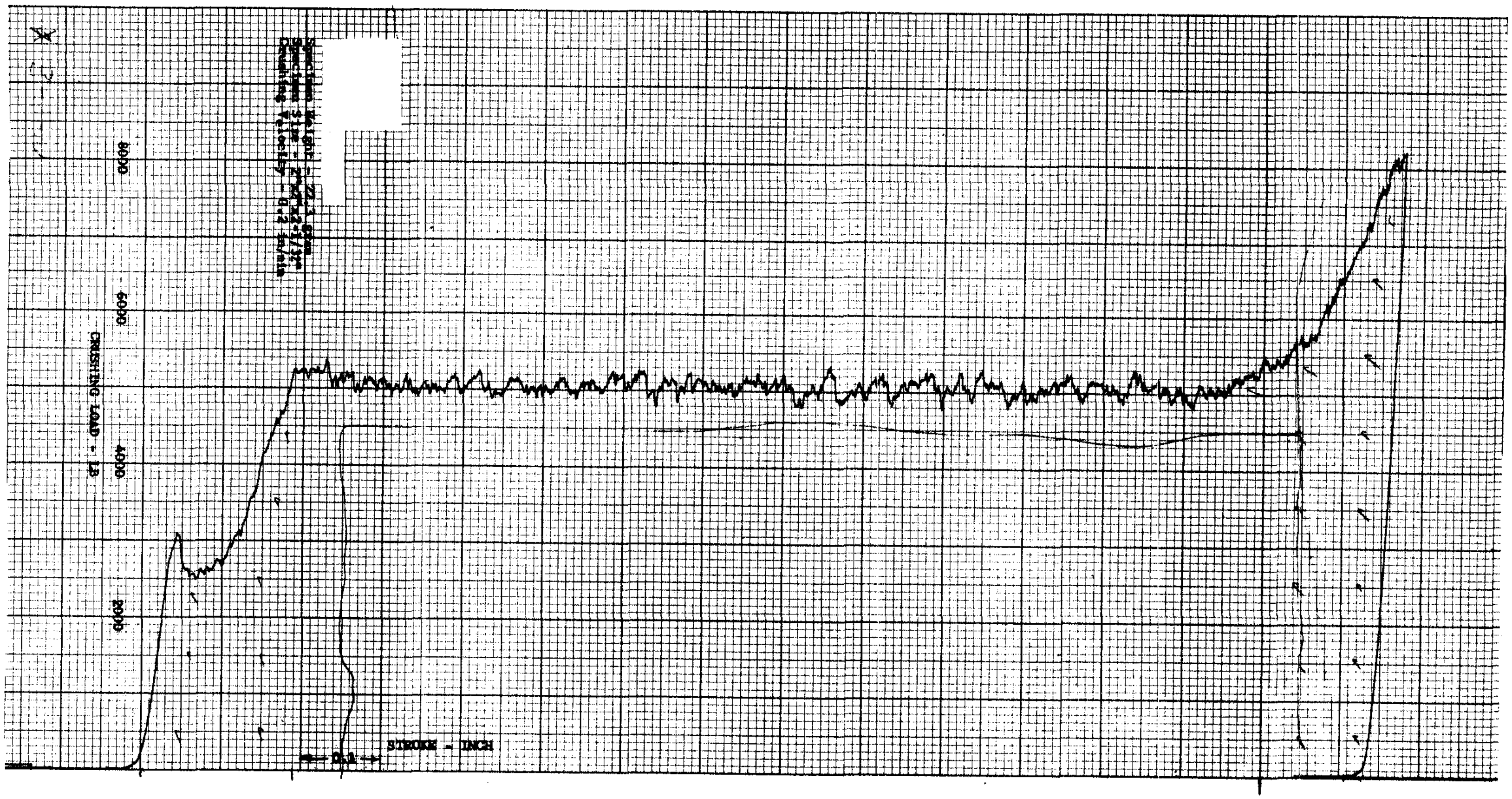
Test B-1-b (Task B-1) - Hexcel Paper Core - 11 pcf



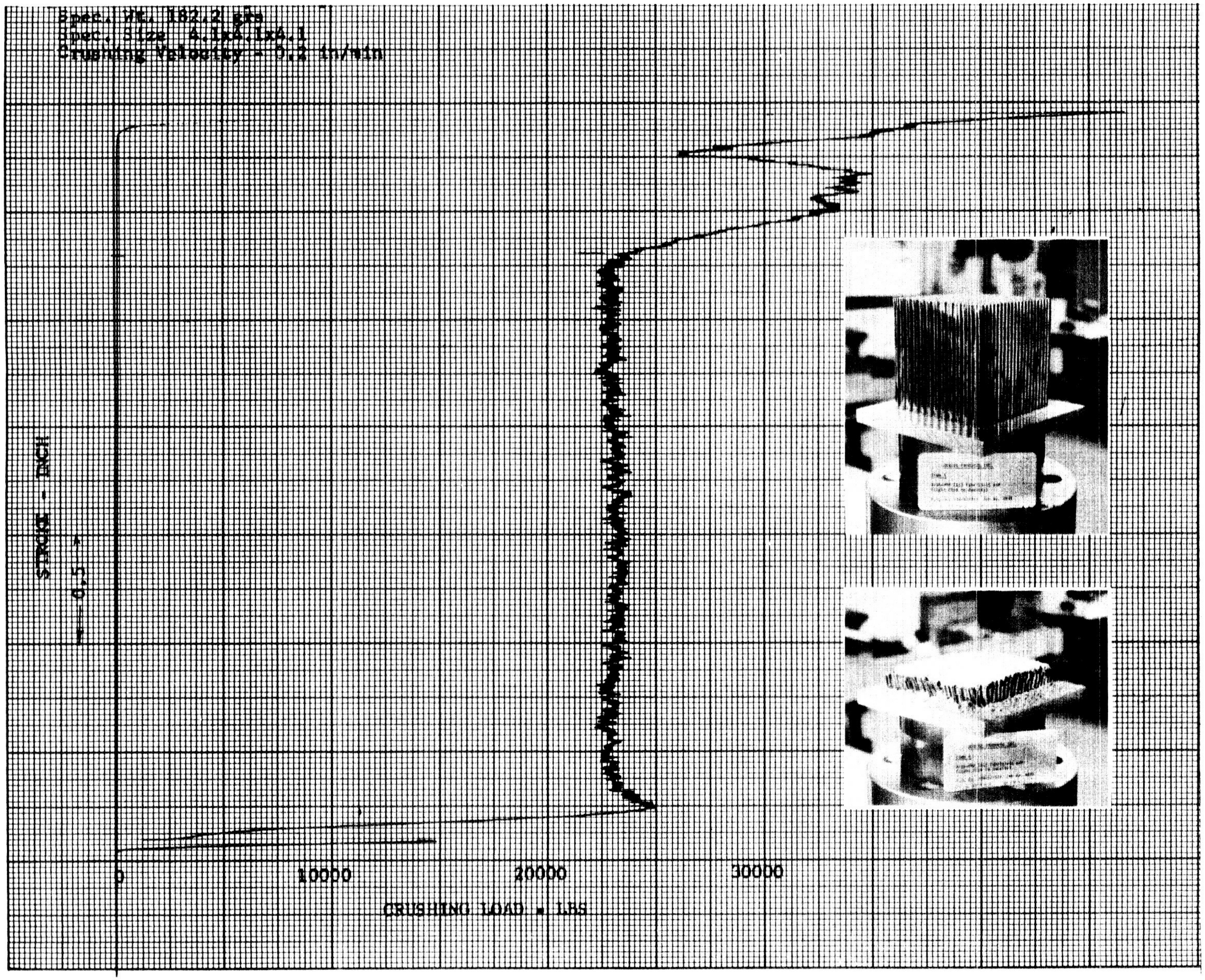
Test B-1-c (Task B-1) - Hexcel Paper Core - 11 pcf



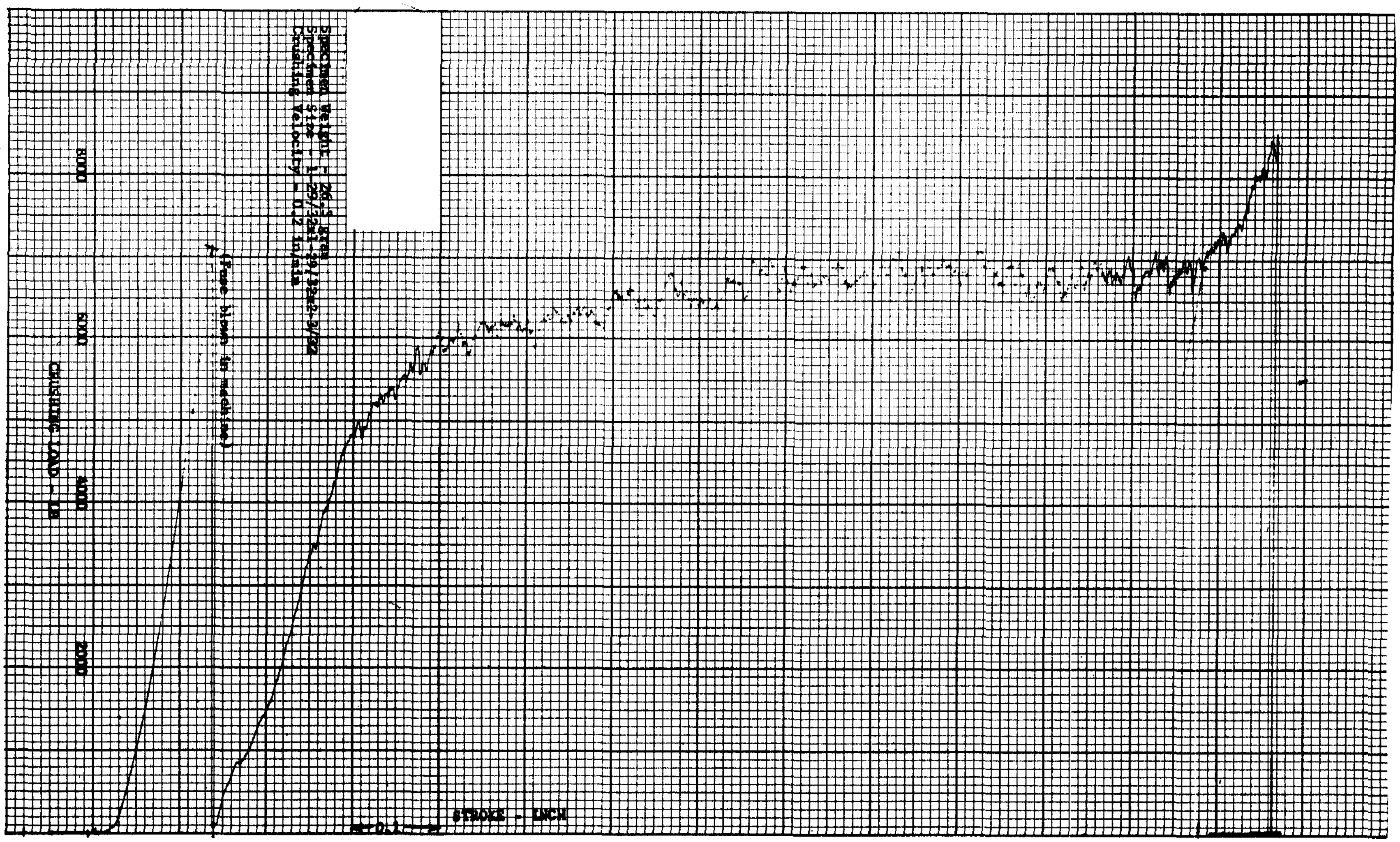
Test B-1-d (Task B-1) - Hexcel Paper Core - 11 pcf



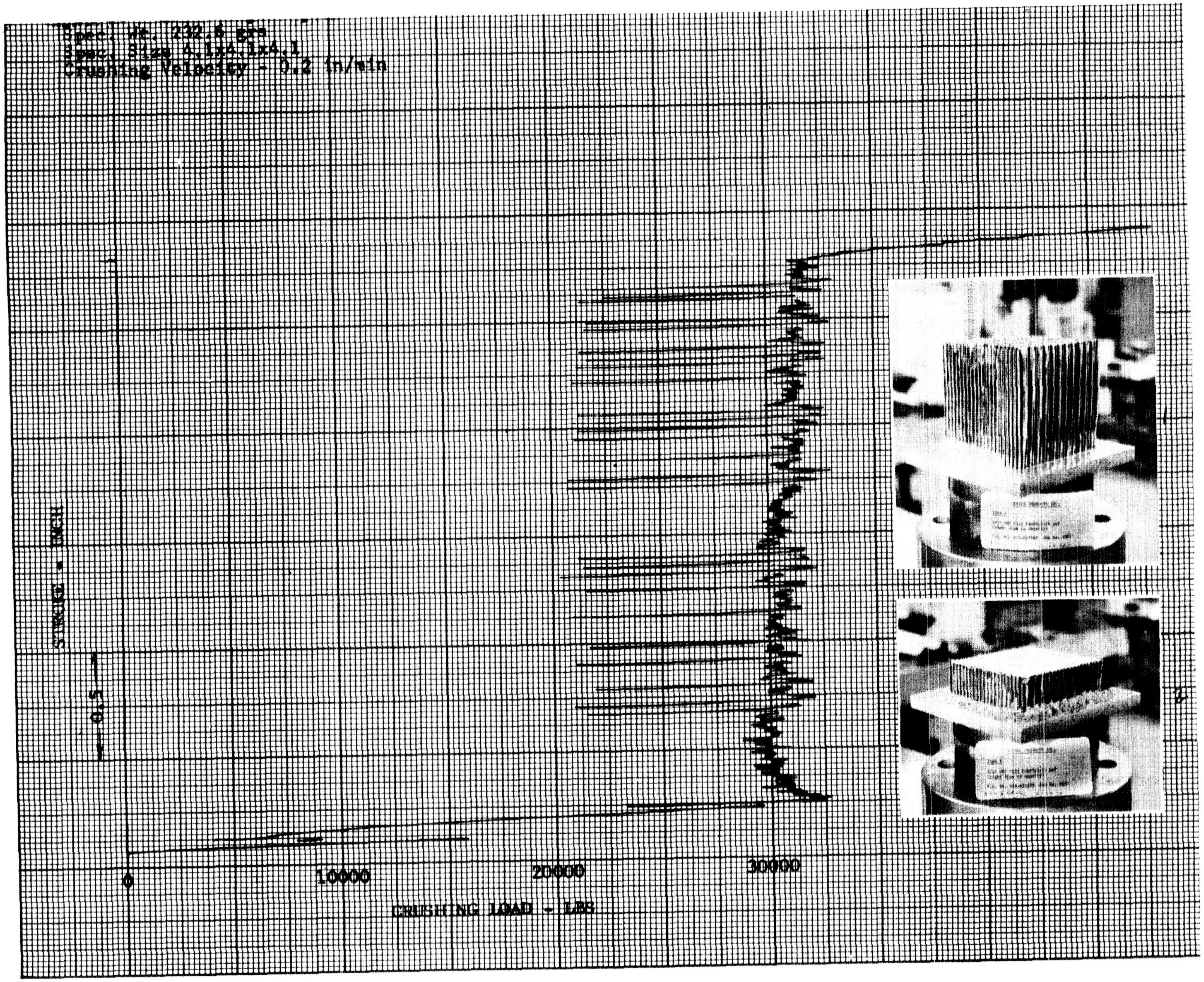
Test B-3-a (Task B-3) - 11 pcf, Thinned Dip Specimen



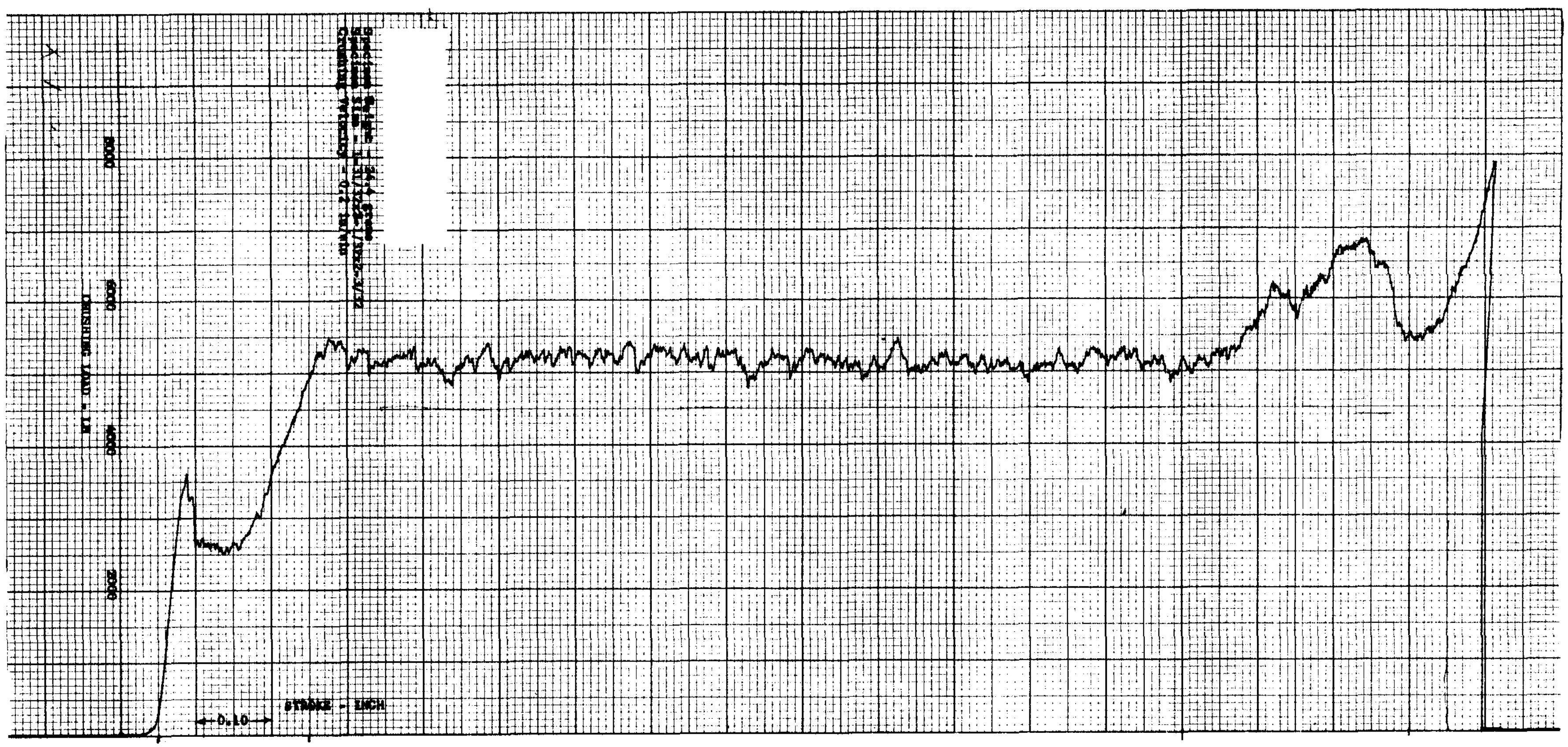
Test B-3-b (Task B-3) - Hexcel Thinned Dip - 11 pcf



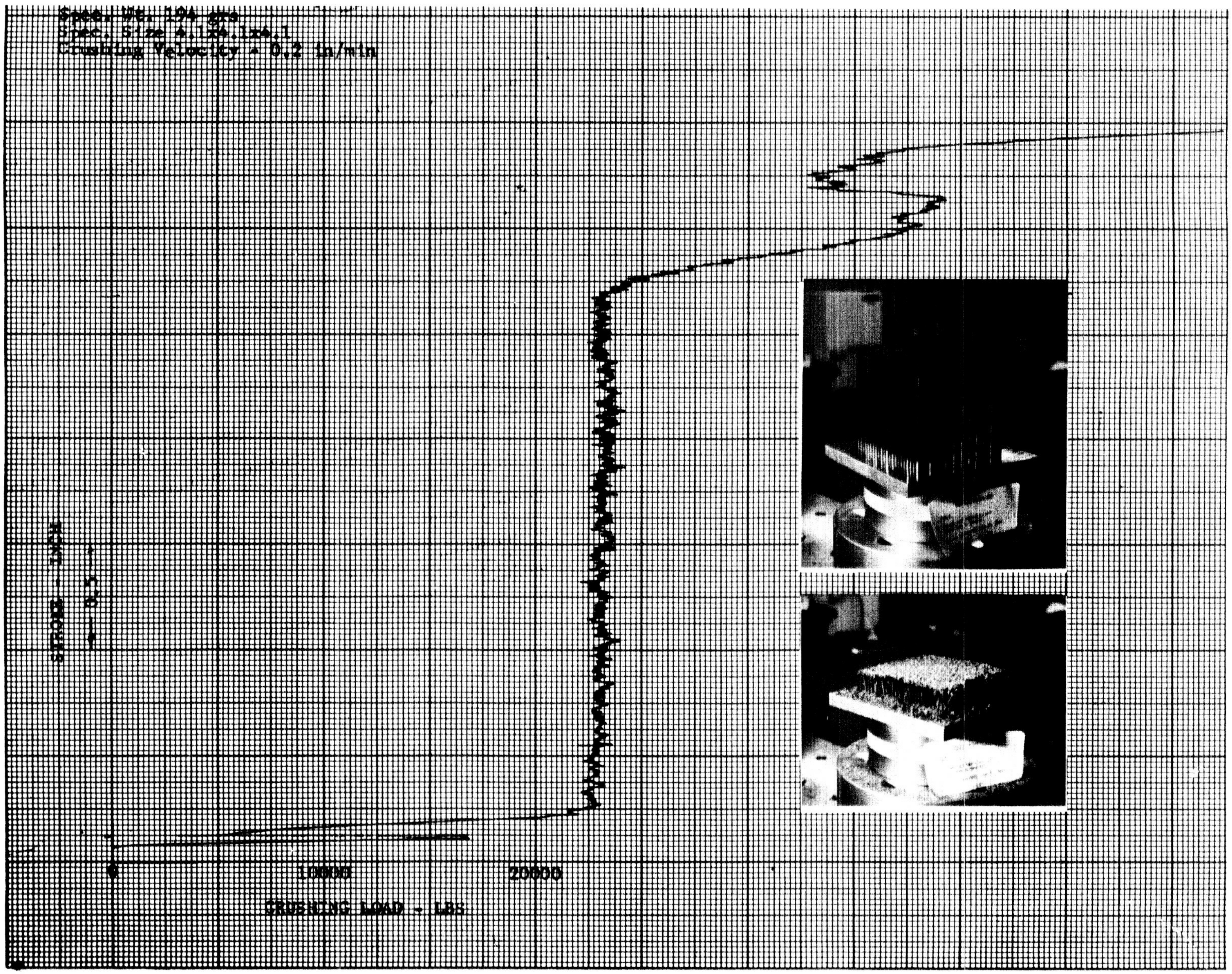
Test B-3-c (Task B-3) - Hexcel Thinned Dip - 14 pcf



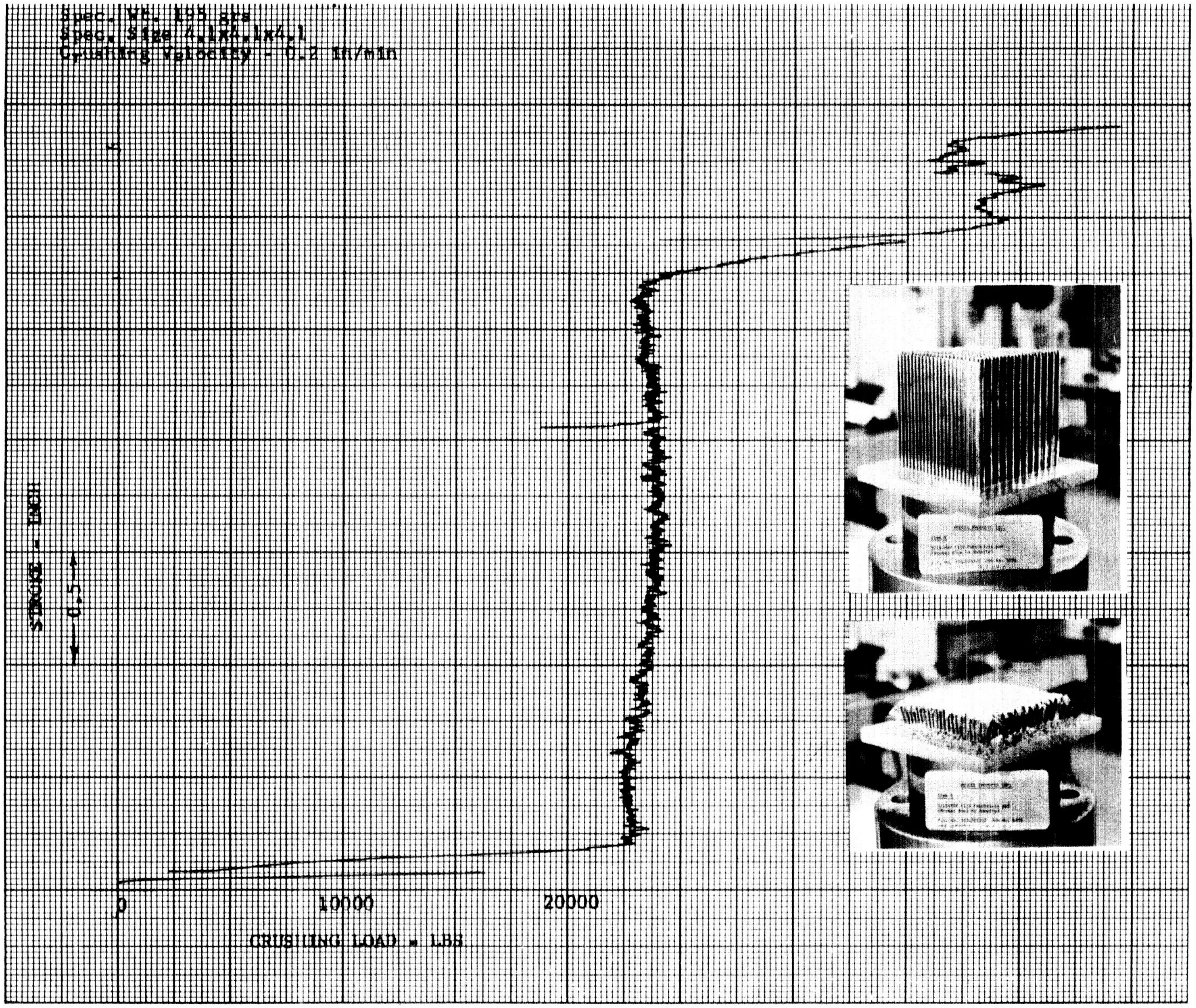
Test B-3-d (Task B-3) - Hexcel Thinned Dip - 14 pcf



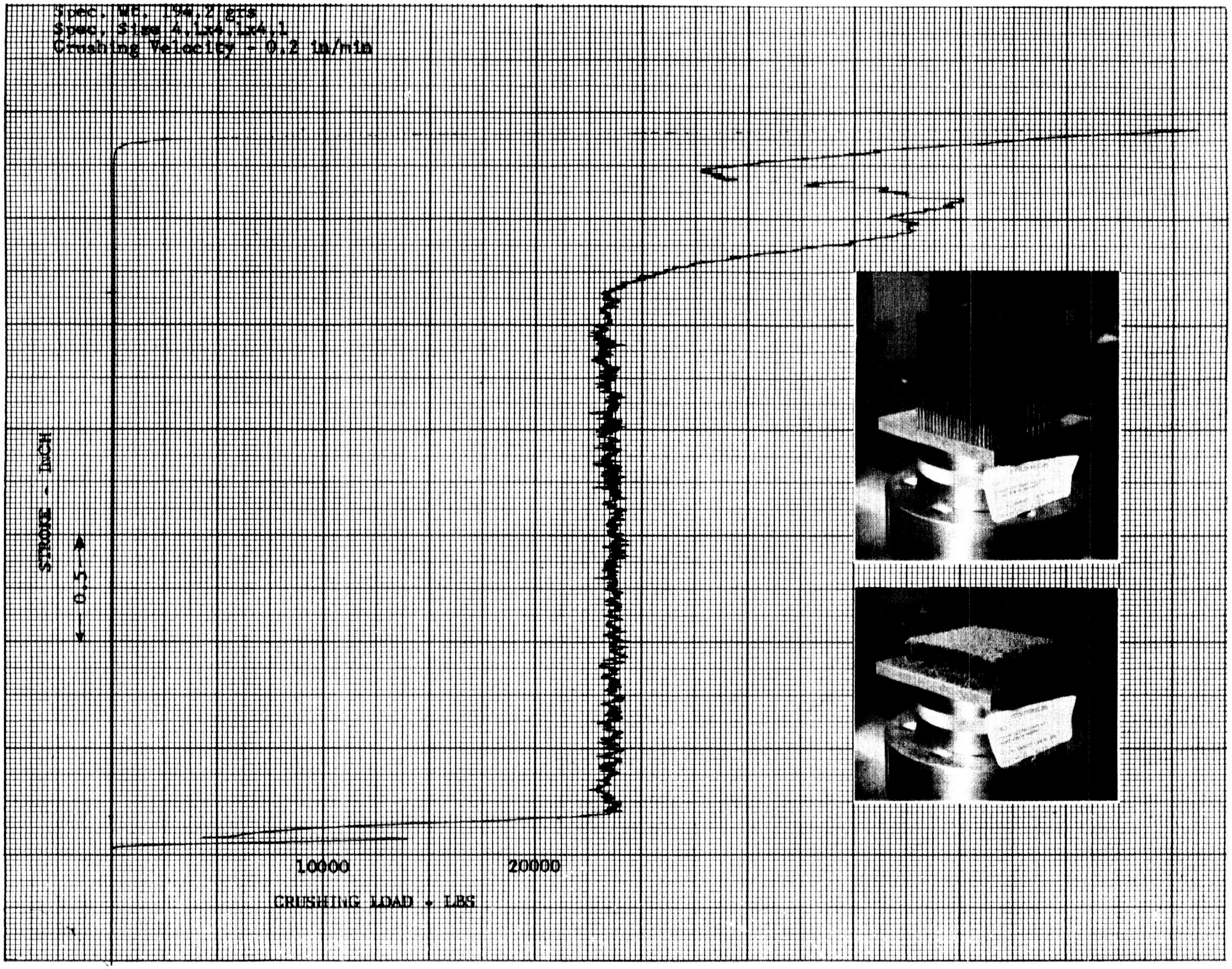
Test X-1-a - Hexcel Semi-Standard 11 pcf



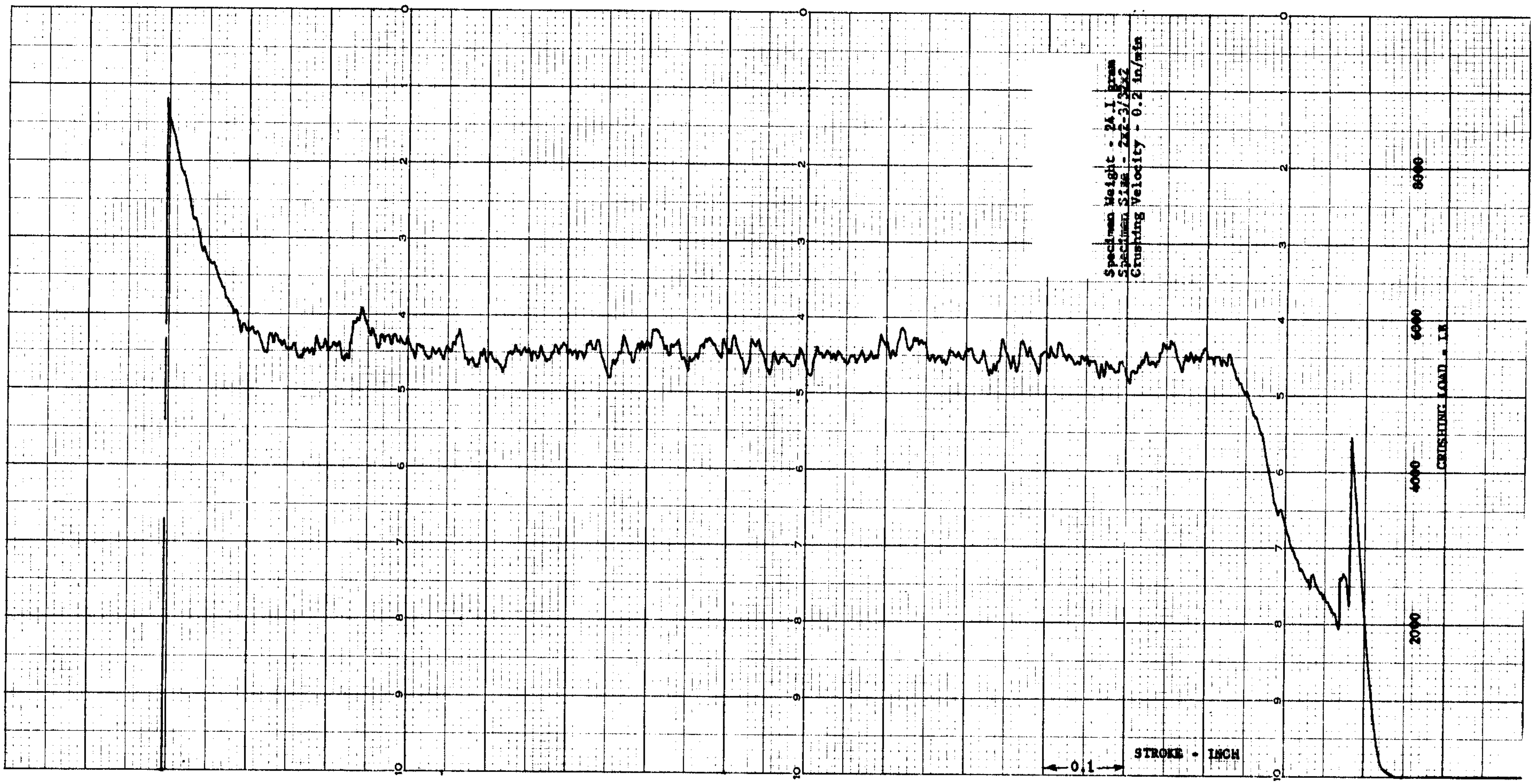
Test X-1-b - Hexcel Semi-Standard 11 pcf



Test X-1-c - Hexcel Semi-Standard 11 pcf



Test X-1-d - Hexcel Semi-Standard 11 pcf



Test X-2-a - Post Cured Hextel Semi-Standard 11 pcf
(20 Hours at 400°F)